Scientific Opportunities with the CBETA Accelerator

Ivica Friščić, William T. Donnelly and Richard Milner (MIT)

Ross Corliss (Stony Brook Uni.)

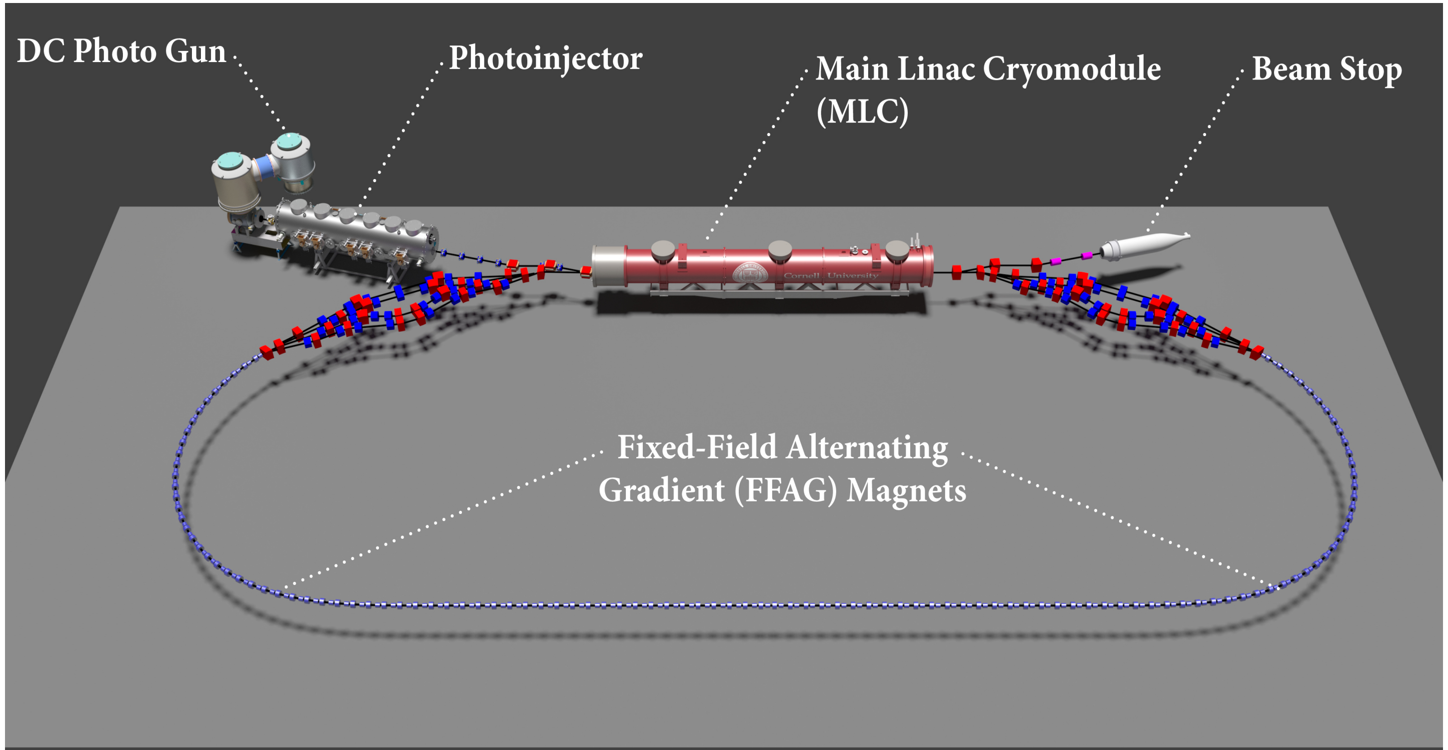
Georg Hoffstaetter (Cornell Uni.)

LOI: SNOWMASS21-RF0_RF0-AF5_AF0_Richard_Milner-036.pdf

Rare Processes and Precision Frontier Townhall Meeting, 02 Oct. 2020

Cornell-BNL Test Accelerator (CBETA) @ Cornell

- Uses superconducting RF (SRF) cavities and Fixed Field Alternating Gradient (FFAG) permanent magnets
- First SRF ERL with multiple acceleration and deceleration passes: Starting with 6 MeV electron beam, electrons are accelerated to 42, 78, 114 and 150 MeV in 4 passes, in subsequent 4 passes energy is fully recovered, 6 MeV electron beam ends in a beam dump (A. Bartnik et al. Phys. Rev. Lett. 125, 044803 (2020))
- Design limit for the beam current is 40 mA

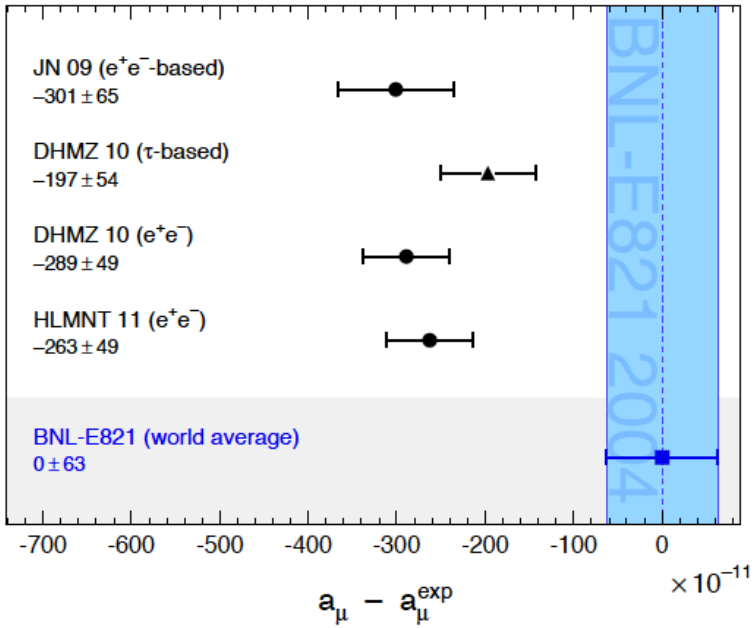


https://www.classe.cornell.edu/Research/ERL/CBETA.html

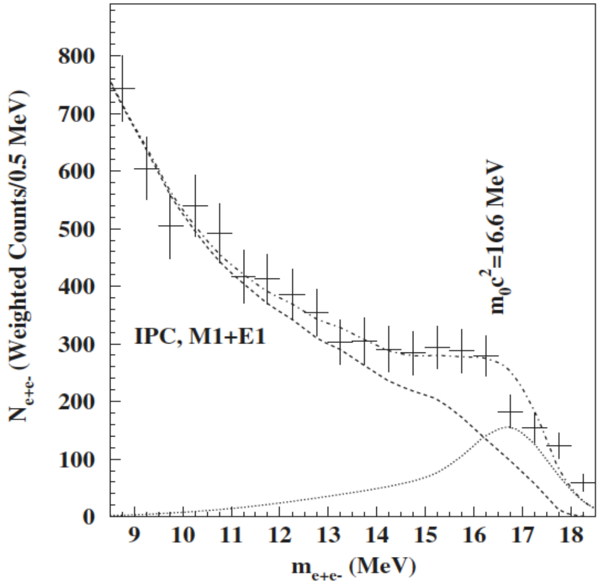
Searching for New Interactions

- We see evidence of significant mass on cosmic scale, which seems to interact only gravitationally – dark matter
- No conclusive evidence of WIMPs (Weakly Interacting Massive Particle) have been found yet
- Additionally, we can search for mediator between the dark mater and the standard model particles – dark photon A': existence of such particle could explain anomalies in low-energy particle, nuclear and atomic experiments which cannot be explained within the standard model

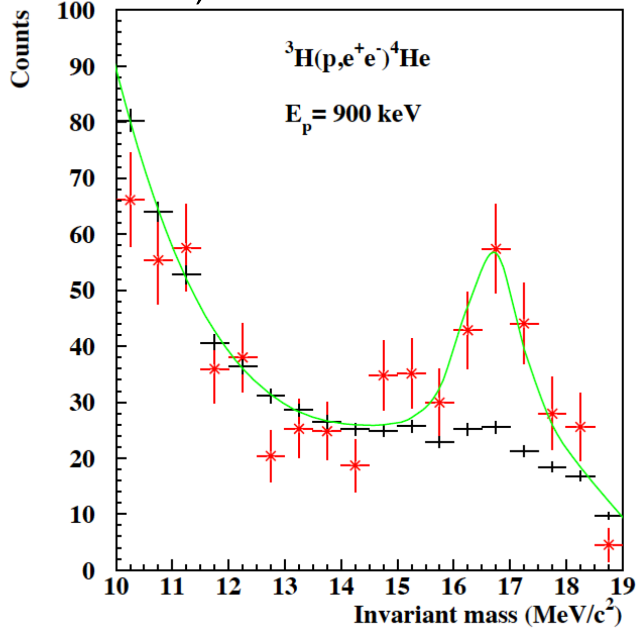
muon g – 2, PDG Chin. Phys. C, 38, 090001 (2014)



^{8}Be* anomaly, A. J. Krasznahorkay et al. Phys. Rev. Lett. 116, 042501 (2016)



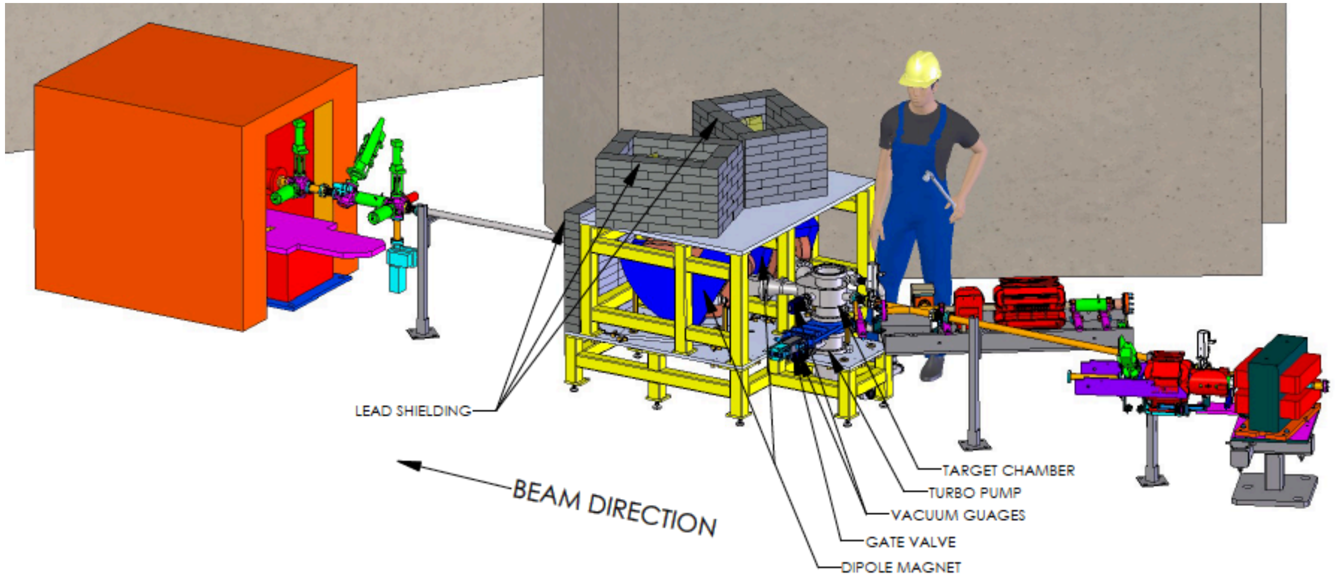
^{4}He* anomaly, A. J. Krasznahorkay et al., arXiv:1910.10459

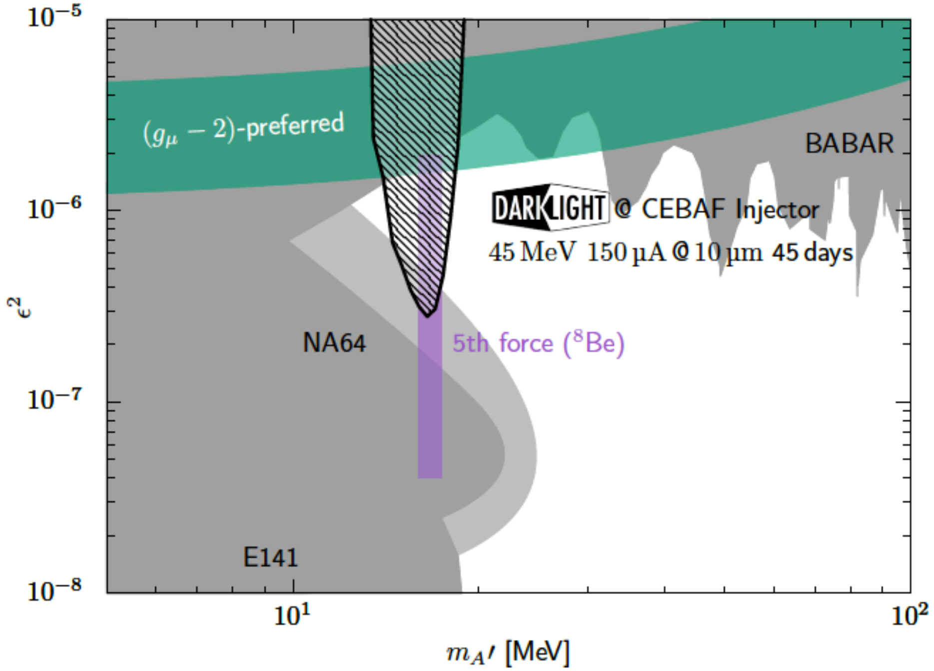


Search for X17 Particle

- Radiative production of dark photon: $e^- + Z \rightarrow e'^- + Z + A'$, $A' \rightarrow e^- + e^+$ (detected in magnetic spectrometers)
- Kinematics: low beam energy provides large opening angle between e^- e^+ pairs
- Luminosity > 10^{35} $1/(cm^2 s)$: 40 mA CBETA and gas-jet target (MAGIX, S. Grieser et al., Nucl. Instrum. Meth. Phys. Res. A 906, 120 (2018).)

DarkLight proposal @CEBAF injector by J. Bernauer et al., PR12-20-001, PAC48 (2020)





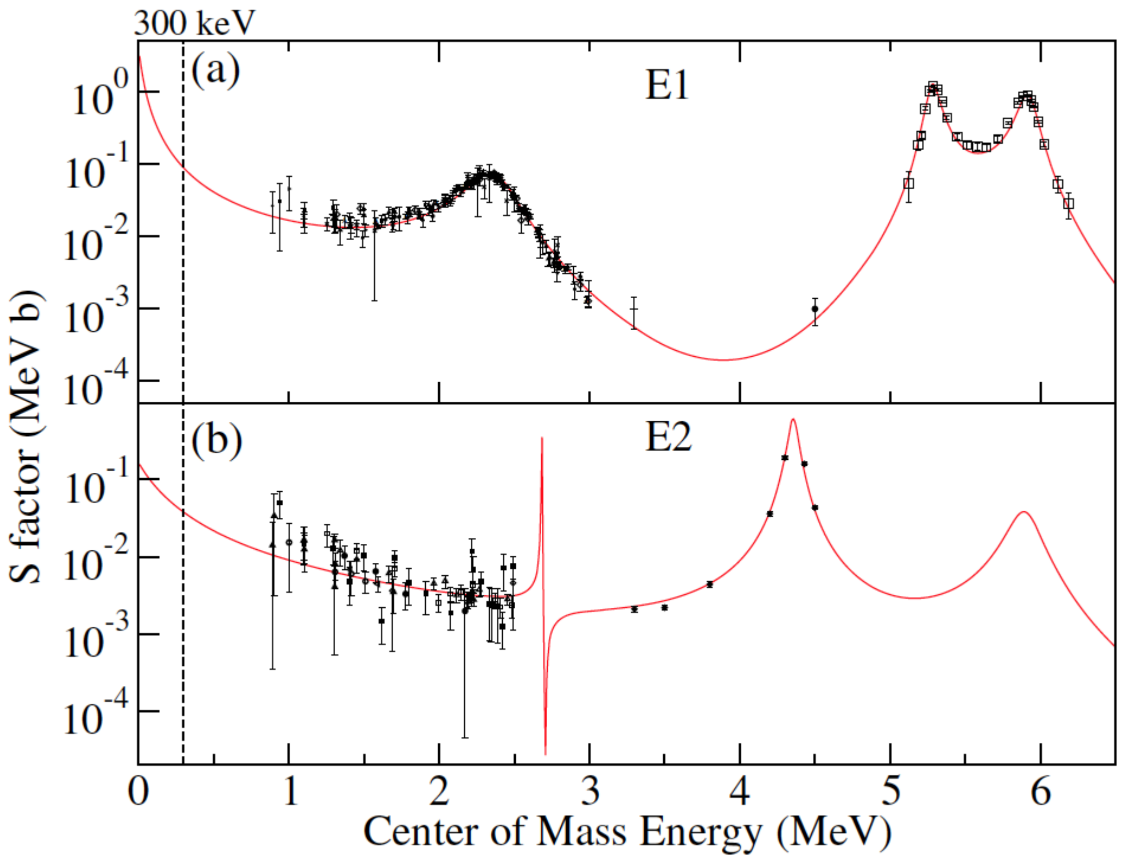
$\alpha + {}^{12}C \rightarrow \gamma + {}^{16}O$ Reaction in Stars

- It determines the $^{12}C/^{16}O$ abundance
- At $T \approx 2 \cdot 10^8$ K, $E_{Gamow} \approx 300$ keV, $\sigma \approx 10^{-5}$ pb => direct measurement of the rate is not feasible
- Rate is measured at larger energy and extrapolated to E_{Gamow} with uncertainties between 20% and 30%
- These uncertainties are the highest among the nuclear input for modeling of the evolution of massive stars
- Rate can be measured:

  a) Direct reactions (either with ^4He or ^{12}C beam)

  b) Indirect reactions (β decay of ^{16}N and Inverse reactions

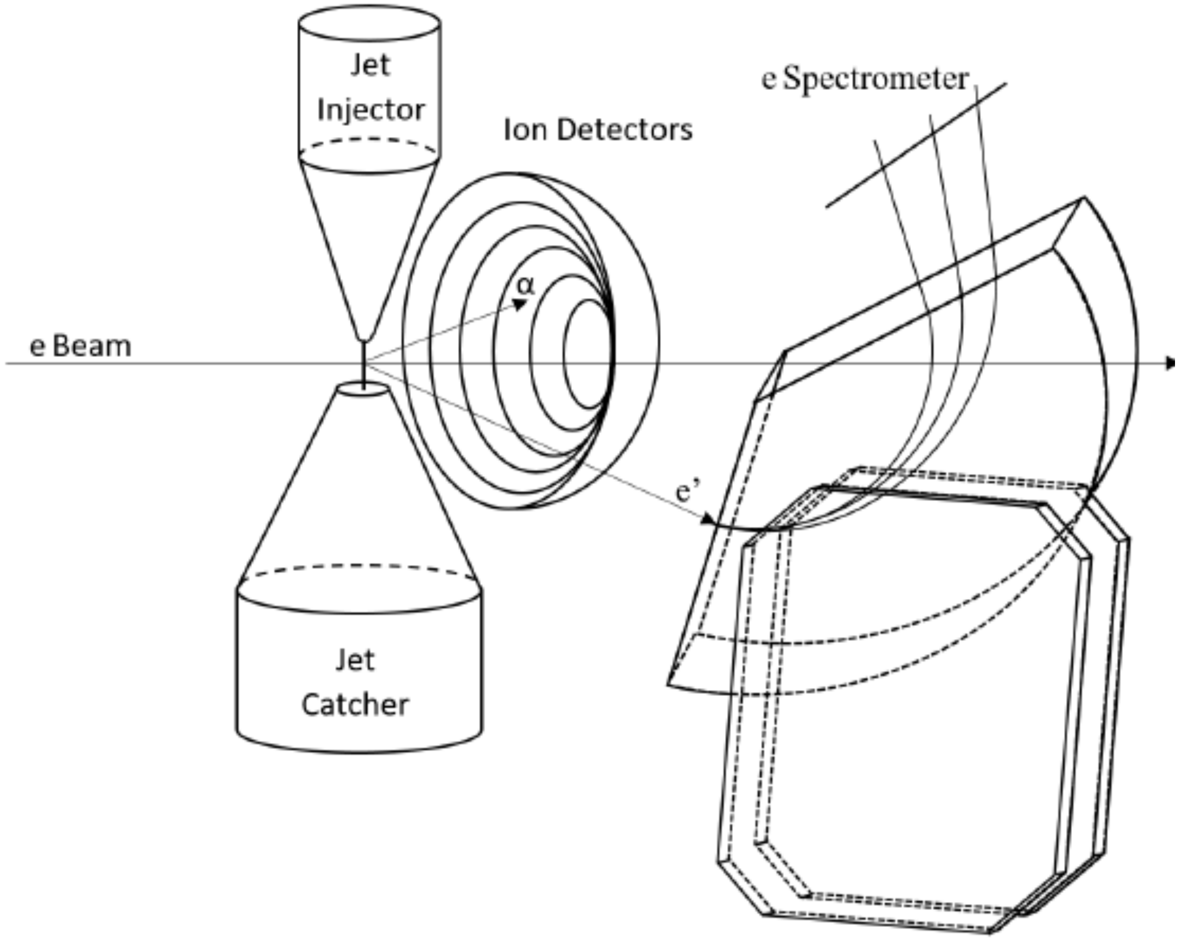
  => photodisintegration and **electrodisintegration**)



R. J. deBoer et al., Rev. Mod. Phys. 89, 035007 (2017) and refereces therein

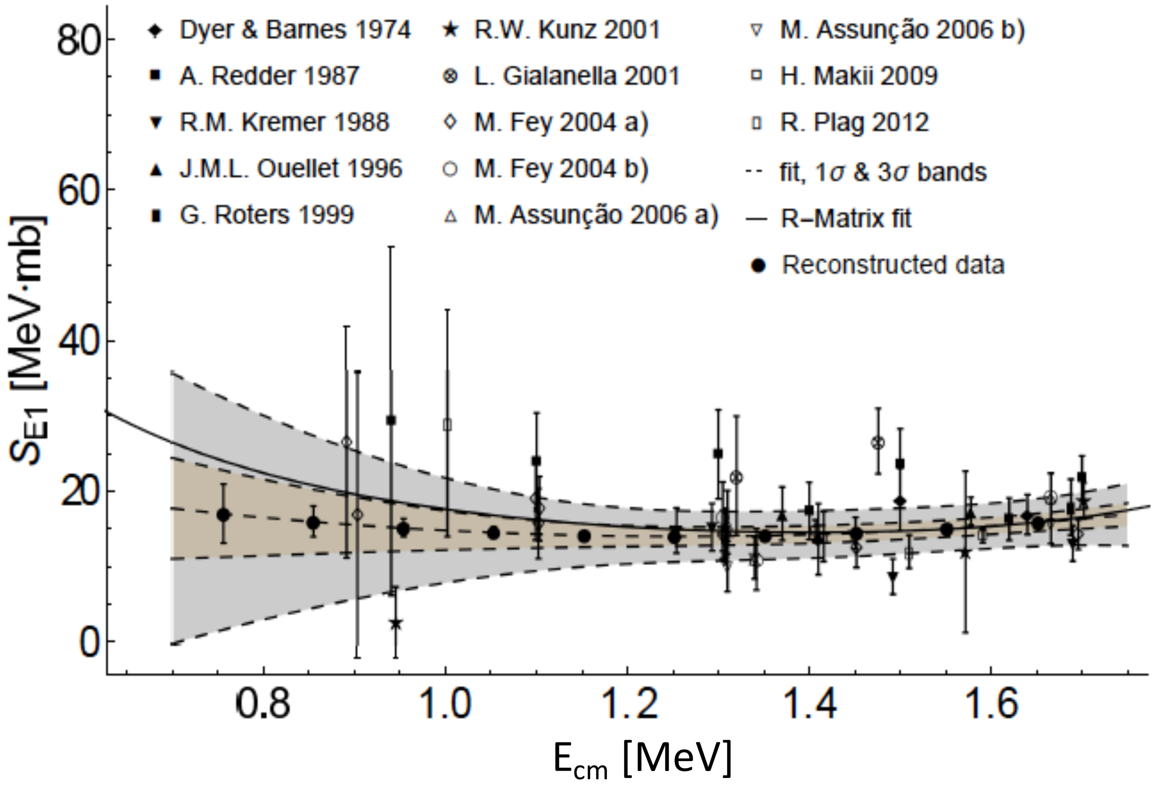
Electrodisintegration of ^{16}O

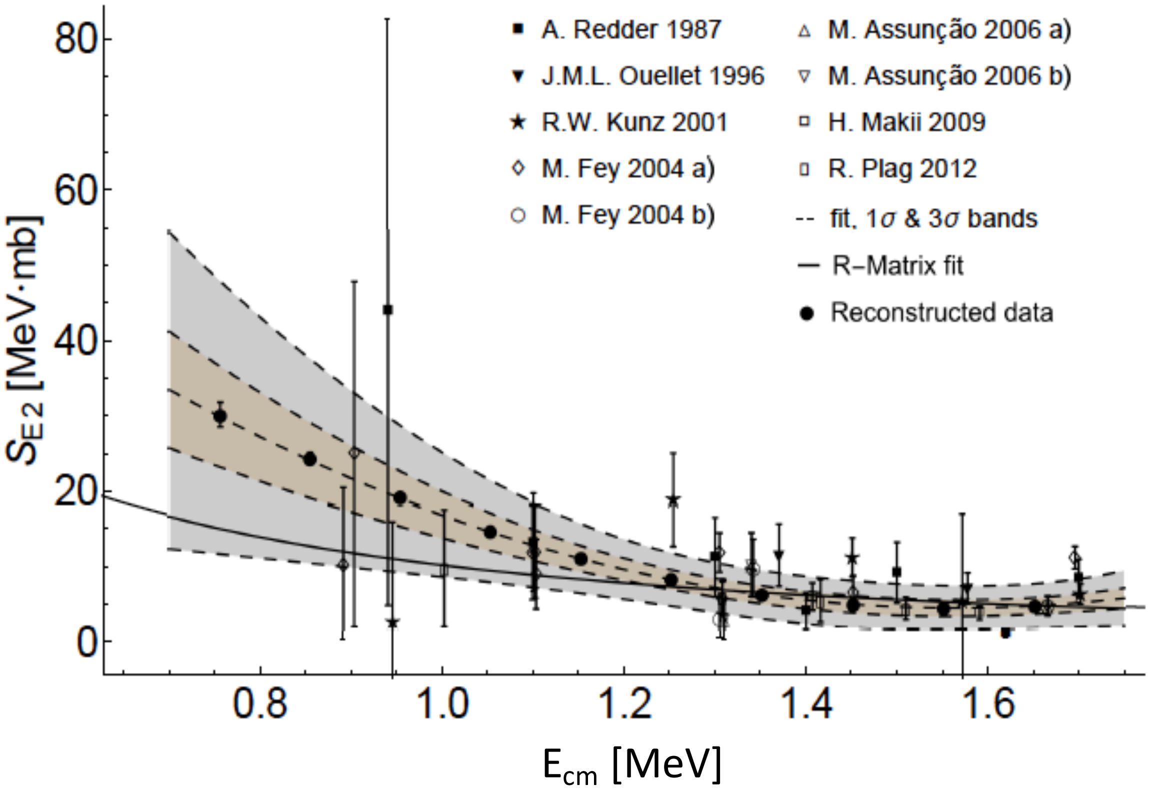
- A feasibility study for using the $^{16}O(e,e'\alpha)^{12}C$ reaction to improve the statistical uncertainties of $^{12}C(\alpha,\gamma)^{16}O$ S_{E1} and S_{E2} factors at stellar energies I. Friščić, W. T. Donnelly and R. G. Milner, Phys. Rev. C 100, (2019) 025804
- We developed formalism which relates the radiative capture reactions and electrodisintegration reactions
- We assumed 100 days of data taking with MAGIX gas jet target at beam energies and current available at CBETA



S-factors and Projected Statistical Uncertainties

- Example for beam energy of E_e= 114 MeV and electron spectrometer at θ_e=15°
- Compared to most accurate data, uncertainties of S_{E1} and S_{E2} are improved by factors 5.6 and 23.9, respectively





Summary and Outlook

- The cutting edge CBETA accelerator enables new low-energy and high-luminosity experiments
- Search for new physics beyond the Standard Model
- Measurement of S-factors for astrophysical relevant reactions
- We will need funds to operate CBETA as an user facility and to build the setup for experiments